Particle Identification

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Particle/Flavor Discrimination

- For the neutrino mass hierarchy measurement, ν_μ CC events are the desired signal
  - Electron neutrinos mainly add noise to the measurement
  - Tau neutrinos are intrinsically anti-correlated with the ν_μ disappearance we are trying to measure (although their reconstructed energy is smeared out by the missing energy carried away by outgoing neutrinos)
  - NC events could theoretically carry some information (at least for ν_μ) but the missing energy and uncertain flavor make this more trouble than its worth
- Determination of the topology (track/no-track) becomes difficult for the small events typical of detectors like PINGU or ORCA
  - Rejection of pure-cascade events could improve sensitivity
  - Measurement of inelasticity could also be useful (Ribordy & Smirnov 2013)

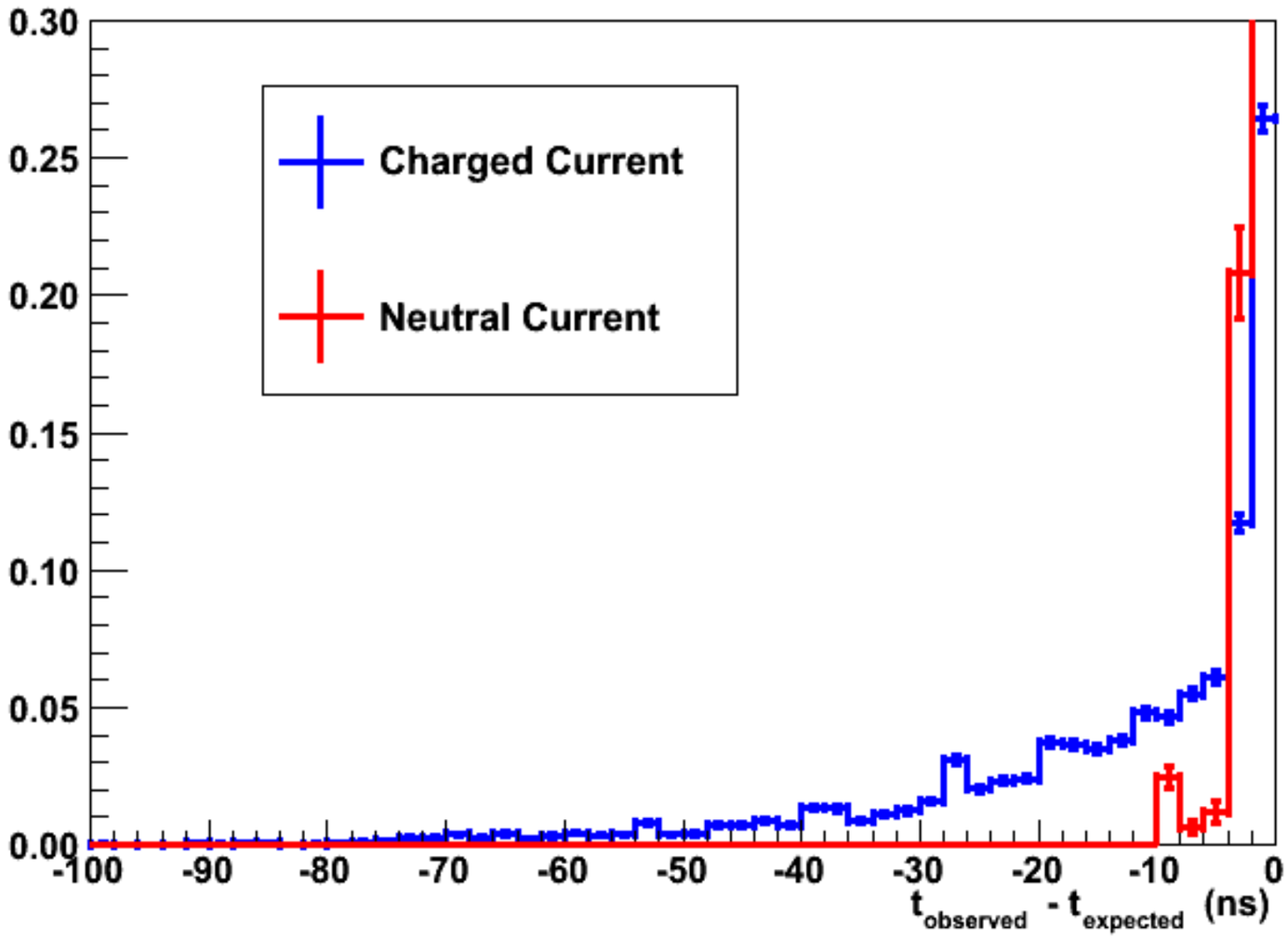
Superluminal Hits

- For small events, the difference between events with tracks and events without tracks can be subtle
  - Many hits are due to light from the vertex cascade, even for ν_μ CC events
  - Cascade photons are emitted close to the Cherenkov angle for the muon – little difference in timing if the emission point is close to the vertex

- We look for a few special “superluminal” hits
  - Detection time too early for propagation at c/n from reconstructed vertex
  - Difference between c and c/n is about 1 ns/m, so this works only at some distance from the vertex
  - Cascades not pointlike – some particles do move at c for some distance
  - Uncertainty in actual vertex position and timing calibration complicate matters further

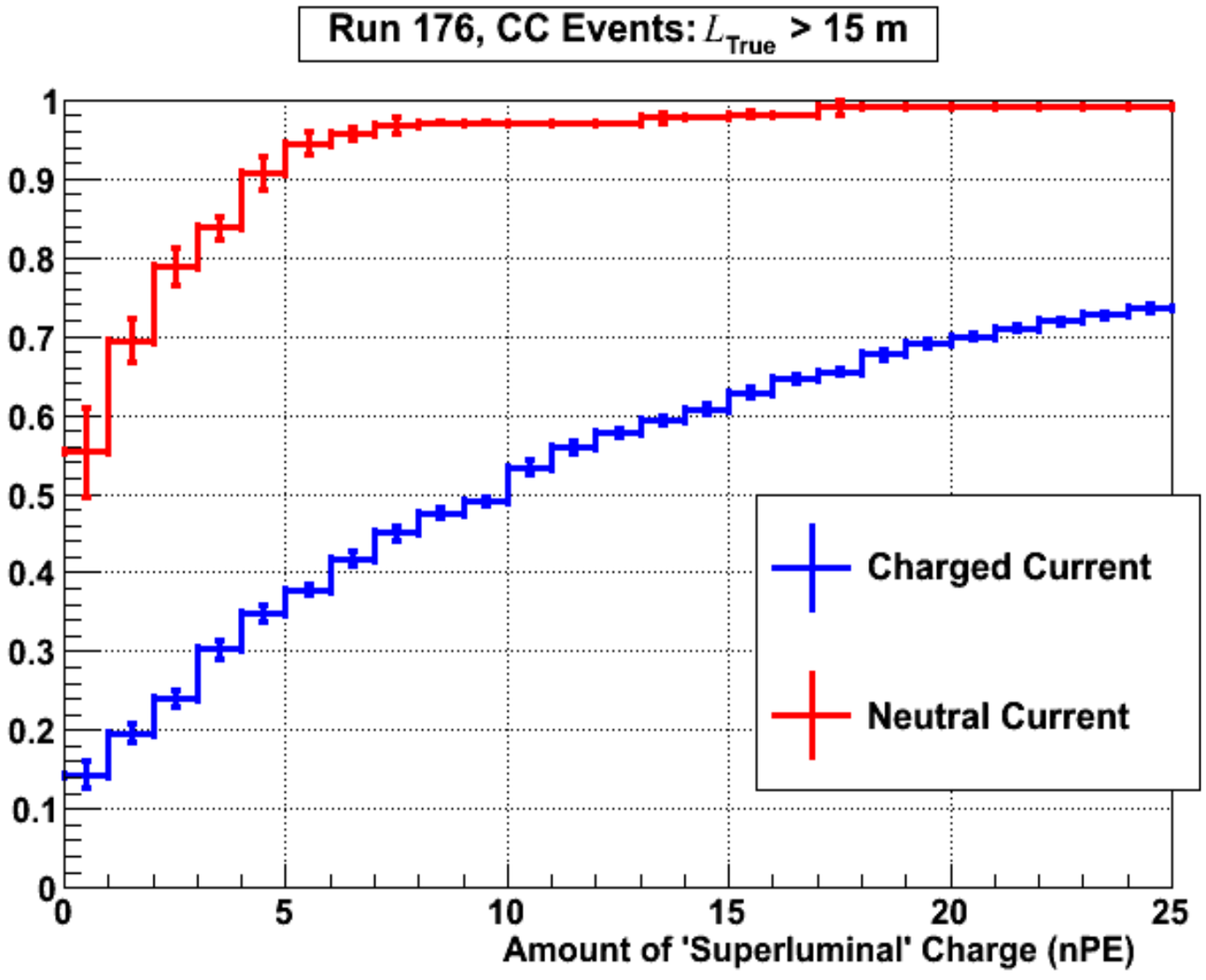
Superluminal Hit Timing

- Charged current muon neutrino events produce substantially higher number of “superluminal” hits
  - Uses MC true vertex information in a simulated PINGU (20-string) detector
  - Neutrino energies from 5–30 GeV with vertices inside PINGU
- Threshold for a hit to be superluminal is about -5 ns, not 0!



An Initial Particle ID Discriminant

- Now use vertex information from an actual reconstruction
  - 8-parameter likelihood fit using the Multinest optimizer
  - Baseline (40-string) PINGU geometry
- Signal sample is ν_μ CC events with interaction vertex within the PINGU volume and track length greater than 15 m
  - Roughly $E_\mu > 3$ GeV
  - Cumulative distributions shown as a function of PEs in (-200, -6) ns window



Efficiency and Performance

- One possible cut value: Q_{SL} > 4 PE
  - Could be folded into analysis as a likelihood term rather than a cut
- Good rejection of NC events with fairly low loss of track-like signal
  - Correlation with other cuts not yet investigated